Journal of the American Mosquito Control Association, 21(4) Supplement:1–3, 2005

REPELLENTS: PAST, PRESENT, AND FUTURE

S. P. FRANCES AND R. A. WIRTZ

ABSTRACT. The use of repellents in protecting people against vector-borne diseases is predicated on the assertion that reducing human/vector contact will reduce the incidence of disease. The methods that have been used in developing countries have been simple to apply and relatively cheap. This article will discuss the use of repellents for protection against vector-borne disease in Southeast Asia and the Southwest Pacific region.

INTRODUCTION

The aim of this article is to discuss the current use of repellents in international health programs, with particular reference to the southwest Pacific region and Southeast Asia.

The use of repellents by villagers and in local government health programs in areas to the north of Australia, such as Papua New Guinea, Solomon Islands, and Vanuatu, is minimal. The health authorities in these countries understand the need to minimize contact between people and vectors; historically, this was attempted by spraying of DDT on the interior walls of houses for malaria-control purposes. This control strategy had mixed success. In recent years, the use of insecticide-treated mosquito bednets has been adopted for malaria control.

AN OVERVIEW OF REPELLENT USE

Studies in the 1960s and 1970s showed the behavior of anopheline vectors of malaria changed as a result of DDT house spraying (Sweeney 1983). The increase in the occurrence of exophilic biting habits and a shift in mosquito biting peaks to the early part of the night, coupled with increased reluctance of villagers to allow their homes to be sprayed, reduced the effectiveness of house spraying. In many countries, the behavioral change in mosquito biting and resting habits means that the use of their limited resources for DDT house spraying and mosquito bednets may be dubious. Research to increase knowledge of the species present and their behavior is warranted and will be an important use for meager research funding.

Although repellents containing diethyl methyl benzamide (DEET) are effective, their use by village people is minimal, primarily due to their inability or reluctance to purchase them because of very low incomes. Therefore, the ultimate cost of repellents has been a major factor in the development of products for sale in developing countries. The development of a repellent-soap formulation containing DEET and permethrin was considered promising, as it was relatively cheap to produce (Yap 1986). The formulation was originally produced by Tom Simmons, Chadstone, Victoria, Australia, initially priced at $US 0.25. The repellent contained 20% DEET and 0.5% permethrin formulated in a bar of soap (Simmons 1985). It was prepared in small blocks (approximate weight = 68 g) and packed in relatively low-cost greaseproof paper. The formulation is applied to wet skin, lathered, and the residue is left on the skin surface and allowed to dry. Several field trials of the effectiveness of the formulation against mosquitoes were conducted in Southeast Asia and Australia (Yap 1986, Charlwood and Dagaro 1987, Frances 1987). Following promising results in these field trials, the formulation was commercialized and marketed as Mosbar (Anonymous 1988). A second formulation, called Moskil, containing only 0.5% permethrin, was also developed and tested (Chiang et al. 1990). Mosbar is available in many countries in Southeast Asia and the Southwest Pacific, including the Solomon Islands. A survey of the personal protection measures used by 308 inhabitants of East Honiara, Solomon Islands, showed a variety of measures were used by people to protect themselves against mosquitoes and potential vectors of malaria (Bell et al. 1997). The survey showed that 10.3% of respondents used Mosbar and 8.4% used unidentified repellents. The study showed that only respondents who used prophylactic drugs or Mortien (pyrethroid aerosol) spray had increased protection against malaria.

Repellents are more widely available and used in some of the economic boom countries in Southeast Asia. In Thailand, a range of repellent formulations is available in most cities and towns. Laboratory studies showed that *Aedes albopictus* (Skuse) adults were relatively sensitive to commercially available repellents, but *Anopheles dirus* Peyton and Harrison was more tolerant (Frances et al. 1993). *An. dirus* is a group of 7 sibling species and *An. dirus* A is an important vector of malaria in the forested border regions of Thailand (Rosenberg et al. 1990). The Royal Thai Army (RTA) is often deployed to these remote regions. RTA troops are knowledgeable about the transmission of malaria and know that mosquitoes that carry the disease should be avoided. They are usually recruited from areas of Thailand with sporadic or no malaria, so they have no inherent immunity, and when deployed to border regions near Cambodia and Burma, are highly susceptible to malaria infection (Eamsila et al. 1994). Living in poorly constructed huts in base camps, these soldiers are encouraged to sleep under a bednet and use mosquito repellents, especially when working after dusk. A variety of repellents are available in Thailand, most formulations retail for less than $US 1.00 for a 50-ml container. In some

RTA camps, repellents are issued by the government, but soldiers sometimes purchase repellent for their own use. Their monthly salary is around $US100, and with their knowledge and concern with protecting themselves against mosquitoes, the investment is a good one for most troops. Recent field studies have shown repellents containing DEET were effective against *Anopheles* spp., including *An. dirus* (Frances et al. 1996a, 1996b).

Other low-cost methods of personal protection used in these countries include mosquito coils, repellents containing locally available active ingredients, such as neem oil formulated in coconut oil (Sharma et al. 1995, Caraballo 2000), and repellents containing citronella and eucalyptus oils (Collins et al. 1993, Trigg 1996).

MILITARY USE OF REPELLENTS

Repellents are used by Australian Defence Force (ADF) personnel within Australia and during deployments overseas. In recent years, ADF personnel have been deployed to United Nations missions in Cambodia, Rwanda, and, currently, in Bougainville, Papua New Guinea, and East Timor. In deployments to areas where malaria and other vector-borne diseases are of concern, personnel are issued a repellent containing 35% DEET, formulated in a gel containing propylene glycol, hydroxypropyl cellulose, and laureth-3. This product is produced by Colbar Australia, and replaced a formulation containing 95% DEET, which had been used since the Vietnam War. ADF personnel are aware of malaria and arboviruses, and the use of personal-protection measures is reinforced in predeployment briefings. These personal-protection measures include wearing appropriate military clothing that has been treated with permethrin, sleeping under a permethrin-treated bednet, taking prescribed prophylaxis for malaria, and applying repellent to exposed skin, especially at dusk and early evening, when mosquitoes are likely to be active.

In mainland Australia, endemic malaria was eradicated in 1962 (formally announced in 1981), and dengue occurs sporadically in the tropical north (Hanna et al. 1998). However, arboviruses, such as Ross River Virus (RRV), Barmah Forest Virus (BFV), and Australian Encephalitis Virus occur in many parts of the country. RRV and BFV occur in all states and territories of Australia, with an average of 5,000 cases annually, and the majority in the state of Queensland. Most cases occur in the summer months, between November and March each year (Russell 1998). Awareness of the mosquito-borne viruses is high, and the health authorities use repellents to supplement mosquito-control programs.

The Australian Army routinely exercises in a variety of situations where there is active transmission of arboviruses. They are often at a higher risk of becoming infected with arboviruses than the civilian population, as the nature of their work brings them into closer contact with mosquitoes. Table 1 shows the response of 55 soldiers who were training in an area of South Central Queensland in March 1999. A questionnaire was prompted by the occurrence of RRV symptoms in 3 soldiers following the exercise. It was subsequently found that 5 individuals had raised IgM antibodies to RRV and 2 to BFV (Clifford et al. 1999). They were asked what repellent they used while they were in the field for the 11-day exercise. Only 21.8% of this small group used the ADF 35% DEET formulation, while 30.9% used RID, which is the most popular formulation in Queensland. The ADF repellent is often the subject of rumor, and many soldiers believe the formulation does not work as well as other formulations they see advertised in the popular press and television.

Table 1. Repellent usage by Australian soldiers in central Queensland, March 1999.

Repellent formulation (supplier)	Deet concentration (%)	Percentage users
Skintastic (S.C. Johnson)	7	3.6
RID (Thorley Laboratories)	16	30.9
Aeroguard (Reckitt and Coleman)	17	7.2
ADF formulation	35	21.8
Bushmans (North Queensland Laboratories)	80	9.1
Multiple/combination	—	23.6
Not identified	—	3.6

FUTURE TRENDS

The future use of repellents by wealthier groups, such as Australians and Americans, will be to use repellents in combination with other personal-protection measures against vectors, such as wearing appropriate clothing, sleeping in screened accommodation or under bednets, and taking suitable prophylaxis and vaccinations. The use of repellents in poorer and developing countries is more problematic. The governments and health authorities in these countries have little or no funding, and village people have little disposable income. The methods that have been developed have been relatively cheap to produce, have used locally available material, and therefore can be purchased by more people in endemic areas for mosquito-borne disease.

ACKNOWLEDGMENTS

We thank R. D. Cooper for comments on the manuscript. This article is published with the approval of the Director General Defence Health Services (Australia).

REFERENCES CITED

Anonymous. 1988. New weapon against malaria. *Health Dev* 56:1.

Bell D, Bryan J, Cameron A, Fernando M, Leafasia J, Pholsyna K. 1997. Malaria in Honiara, Solomon Islands: reasons for presentation and human and environmental factors influencing prevalence. *Southeast Asian J Trop Med Public Health* 28:482–488.

Caraballo, AJ. 2000. Mosquito repellent action of Neemos®. *J Am Mosq Control Assoc* 16:45–46.

Charlwood JD, Dagoro H. 1987. Repellent soap for use against malaria vectors in Papua New Guinea. *Papua New Guinea Med J* 30:301–303.

Chiang GL, Tay SL, Eng KL, Chan ST. 1990. Effectiveness of repellent/insecticidal bars against malaria and filariasis vectors in peninsular Malaysia. *Southeast Asian J Trop Med Public Health* 21:412–417.

Clifford, K, Frances S, Russell B, and Nasveld P. 1999. Preventative health advice to deploying units. *Aust Mil Med* 8:7–12.

Collins DA, Brady JN, Curtis CF. 1993. Assessment of the efficacy of quwenling as a mosquito repellent. *Phytotherapy Res* 7:17–20.

Eamsila C, Frances SP, Strickman D. 1994. Evaluation of permethrin-treated military uniforms for personal protection against malaria in northeastern Thailand. *J Am Mosq Control Assoc* 10:515–521.

Frances SP. 1987. Effectiveness of DEET and permethrin, alone, and in a soap formulation as skin and clothing protectants against mosquitoes in Australia. *J Am Mosq Control Assoc* 3:648–650.

Frances SP, Eamsila C, Pilakasiri C, Linthicum KJ. 1996a. Effectiveness of repellent formulations containing DEET against mosquitoes in northeastern Thailand. *J Am Mosq Control Assoc* 12:331–333.

Frances, SP, Eikarat N, Sripongsai B, Eamsila C. 1993. Response of *Anopheles dirus* and *Aedes albopictus* to repellents in the laboratory. *J Am Mosq Control Assoc* 9:474–476.

Frances, SP, Klein TA, Hildebrandt DW, Burge R, Noigamol C, Eikarat N, Sripongsai B, Wirtz RW. 1996b. Laboratory and field evaluation of DEET, CIC-4, and AI3–37220 against *Anopheles dirus* (Diptera: Culicidae) in Thailand. *J Med Entomol* 33:511–515.

Hanna, JN, Ritchie SA, Merritt AD, van den Hurk AF, Phillips DA, Serafin IN, Norton RE, McBride WJH, Gleeson FV, Poidinger M. 1998. Two contiguous outbreaks of dengue type 2 in north Queensland. *Med J Aust* 168:221–225.

Rosenberg, R, Andre RG, Somchit L. 1990. Highly efficient dry season transmission of malaria in Thailand. *Trans R Soc Trop Med Hyg* 84:22–28.

Russell, RC. 1998. Mosquito borne arbovirus in Australia: the current scene and implications of climate change for human health. *Int J Parasitol* 28:955–969.

Sharma SK, Dua VK, Sharma VP. 1995. Field studies on the mosquito repellent action of neem oil. *Southeast Asian J Trop Med Public Health* 26:180–182.

Simmons TE. 1985. Insect-repellent and insecticidal soap composition. UK Patent No. 2160216A.

Sweeney AW. 1983. A review of chemical control of malaria vectors in the south-west Pacific region. In: Laird M, Miles JW, eds. *Integrated mosquito control methodologies Volume 1. Experience and components from conventional chemical control.* London, United Kingdom: Academic Press. p 143–158.

Trigg JK. 1996. Evaluation of a eucalyptus-based repellent against *Anopheles* spp. in Tanzania. *J Am Mosq Control Assoc* 12:243–246.

Yap HH. 1986. Effectiveness of soap formulations containing DEET and permethrin as personal protection against outdoor mosquitoes in Malaysia. *J Am Mosq Control Assoc* 2:63–67.